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THE PLACE OF LIBERAL CONCENTRATE FEEDING TO DAIRY CATTLE

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For the past 50 years we have been feeding our dairy herds concentrates in proportion to milk production with some adjustment for the quality of the forage available. This practice has resulted in feeding energy to animals at about requirement. Generally, the energy from concentrates has been more expensive than that from forages. Therefore, there has been considerable emphasis on the feeding of large quantities of forages.

During recent years the cost of energy in concentrates has become more competitive in relation to forages. In some areas of the country this has meant a considerable increase in the feeding of concentrates to dairy cattle and, in fact, has led to heavy or liberal grain feeding. There is no question but that heavy grain feeding results in an increased level of milk production and in some areas decreases the cost.

Many schemes have been proposed for the heavy feeding of concentrates such as ad libitum feeding of concentrates, limitation of forage intake, challenge feeding, lead feeding, and narrowing of the grain to milk ratio. It is not clear at this point which one of these procedures would be the most advantageous to use. The key to any of the procedures seems to be liberal feeding before and immediately after calving in order to stimulate a high peak of production as soon as possible after parturition.

Many considerations need to be weighed in deciding whether or not to embrace the liberal concentrate feeding program. The most important consideration is the relationship between the price of feed, particularly the concentrates, and the price of milk at the farm. Another consideration is the relative price of forage compared to concentrate. As a general rule, on a net energy basis, a ton of hay should be worth about half as much as a ton of concentrate. Thus, if concentrate costs $60 per ton, a ton of good quality hay would be worth $30.

Another consideration is the fact that forage from a nutritional standpoint should form the backbone of any dairy feeding program since it furnishes the minerals and vitamins so necessary for the health and reproduction of the herd. Intake of forage may be reduced somewhat with liberal concentrate

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feeding. Although vitamins and minerals can be added at fairly low cost to the concentrate portion of the ration, the results of long-term experiments utilizing this procedure have not been reported.

The next consideration, which also involves economics, is the fact that as more energy is fed the law of diminishing returns sets in. Thus, as the level of concentrate feeding increases, each additional successive pound of grain produces less milk.

There is considerable information available at this time which provides a basis for deciding what level of concentrate feeding will be most profitable to use. A suggested method of calculating economical feeding rates of concentrates is presented. The background information on which this method is based, including a few typical experimental trials and discussions of economic and other implications. is presented.

GRAIN FEEDING EXPERIMENTS

Michigan Experiment

Eighteen Holstein cows were divided into three comparable groups on the basis of milk production, age, and body weight and were assigned to one of three experimental treatments approximately 36 days postpartum. During the subsequent 260-day period, as shown in table 1, all cows were offered 40 pounds of corn silage per day.

Table 1. Michigan experiment -- average daily milk production, feed consumption, and body weight change for the 260-day experimental period[1/]

Item	Group		
	1	2	3
Milk production (Lb./day):			
Actual	37.9	41.0	48.2
FCM	36.6	39.9	46.0
Feed consumption (Lb./day):			
Grain	11.9	17.0	36.0
Hay	24.4	13.9	4.9
Corn silage	38.2	37.7	34.2
Body weight change	+0.64	+0.91	+0.94
Grain to milk ratio	1:3.5	1:2.5	1:1.3
Income over feed (dollars/day):	1.07	1.22	1.22

1/ Grain $40/ton, hay $20/ton, corn silage $7/ton, milk $4.60/cwt. Adapted from the work of Brown, L. D., and others, Effect of high-level grain feeding on milk production response of lactating dairy cows. J. Dairy Sci. 45:1184-1187. 1962.

In addition, cows in Group 1 received alfalfa hay ad libitum and grain at the rate of 1.0 pound for each 3.5 pounds of milk. Cows in Group 2 were limited to 15.0 pounds of alfalfa hay per day and the grain feeding increased to 1.0 pound for each 2.5 pounds of milk. Group 3 cows were limited to only 5.0 pounds of alfalfa hay per day and grain was fed ad libitum, which resulted in an intake of 1.0 pound of grain for each 1.3 pound of milk. The hay and corn silage were considered to be of excellent quality.

Production increased, on the average, as the level of grain fed was increased. However, all cows did not respond to high-level grain feeding. Four of the six cows in Group 3 produced from 2,550 to 4,970 pounds more milk than was expected; the other two cows produced milk at their respective calculated level. The reason these two cows did not respond is not known, but it may have been due to the lack of genetic potential for high-level production. These data indicate that increasing the nutritional level of cows that do not have the genetic potential for high-level milk production will not result in increased milk production. In no case did cows have difficulty with digestive disturbance or going off feed.

This experiment was not designed to study the efficiency of milk production in terms of pounds of total digestible nutrients (TDN) required per pound of milk. However, when net efficiency was calculated, the cows in Group 2 required 0.39 of a pound of TDN per pound of fat-corrected milk (FCM) compared to 0.49 and 0.52 of a pound, respectively, for Groups 1 and 3 ($P < 0.05$). Based on this work, it appears that feeding grain to appetite will increase milk production markedly. The investigators point out that such a practice will aid in determining the genetic potential of the cow for high milk production. The liberal feeding of concentrate, under Michigan conditions, resulted in increased profit.

Experiment at Puyallup, Wash.

An experiment[2/] was conducted in which milk production responses were compared for cows fed hay and concentrate at two levels in addition to free-choice feeding of high-moisture hay-crop silage. The rations are shown in table 2.

Table 2.· Rations fed in Puyallup, Wash., experiment

Ration no.	Concentrates per pound of milk over 18 lbs	Hay per 100 pounds of body weight	Hay-crop silage
1	0.6	1	Free choice
2	.3	1	Free choice
3	.6	.5	Free choice
4	.3	.5	Free choice

2/ Murdock, F. R., and Hodgson, A. S. A case for conservative grain feeding. Hoard's Dairyman, May 25, 1962.

Sixteen Holstein cows were used in the experiment designed so that all cows were fed each ration during a 28-day feeding period. The hay was a good quality, second-cutting of grass-clover mixture produced in the area. The results are shown in table 3.

Table 3. Puyallup, Wash., data--effects of grain feeding levels on production, weight changes, and returns

Item	Ration 1	2	3	4
Feed consumption (lb/cow/day):				
Mixed hay	13.3	13.5	6.9	7.0
Grass silage (24.5% D.M.)	59.8	67.5	76.5	82.4
Concentrates	20.1	9.5	19.5	9.5
Milk production and body-weight changes:				
Lb/cow/day[1/]	51.7	47.8	51.6	48.0
Lb. gain (+) or loss (-) (per cow/day)	+1.00	-0.28	+1.03	-1.15
Economic summary (dollars)[2/]:				
Gross returns from milk	2.22	2.06	2.22	2.06
Daily feed costs	1.02	.71	.98	.68
Returns over feed cost	1.20	1.35	1.24	1.38

1/ 4% fat-corrected milk

2/ Returns based on milk at $4.30/cwt; hay at $24/ton; silage at $7/ton; and concentrates at $65/ton. Taken from Hoard's Dairyman, 5/25/62.

The cows were good producers, averaging 15,410 pounds of milk and 572 pounds of fat for 305 days. The greater part of these records were made under feeding conditions very similar to those used during the experiment.

The investigators point out that by averaging the data for the groups fed the high levels and those fed the low levels of concentrates, that the cows fed high levels produced 3.75 pounds more milk daily from an additional 10.3 pounds of concentrates. At the prices indicated, the extra milk would have a value of 16 cents at a feed cost of 31 cents (33-1/2 cents cost of additional grain less about 2-1/2 cents difference in cost of silage consumed). Thus, under the prevailing price relationships in this experiment, liberal concentrate feeding did not pay. It seems obvious from the Michigan and Washington experiments, that profit from heavy grain feeding is determined by feed price relationships. In the Michigan experiment, grain cost $40/ton; in the Washington experiment it cost $65/ton.

Montana Experiment

Three treatments were compared: (a) hay as the sole ration, (b) hay with 0.4 pound concentrate, and hay with 0.8 pound concentrate above 20 pounds FCM per day. Two continuous feeding experiments with 30-day preliminary periods and 100-day experimental periods were conducted during 2 different years. Each treatment involved 5 cows for each year. The hay was nearly all second-cutting alfalfa with a leaf content comparable to that of U.S. No. 2. Adding concentrate resulted in highly significant increases in milk production, body weight, total dry matter consumption, and total estimated net energy

consumption (table 4 and fig. 1). Except for the first 20 days when milk production level adjusted to the new feeding level, no differences existed in rate of decline. Under Montana conditions, with hay at $20/ton, concentrate $50/ton, and milk at $4/100 pounds, there was a small advantage to feeding concentrate. The profit per cow per day for 3 levels of feeding hay, hay with 0.4 pound of concentrate and hay with 0.8 pound concentrate above 20 pounds FCM per day was $0.95, $1.02, and $1.04.

Table 4. Results of feeding cows for 2 years on experimental rations--Montana. /Daily treatment means adjusted on a per-cow basis using regression from combined analysis of variance/

Concentrate per pound above 20 pounds FCM	Total therms	Weight gain or loss	Dry Matter		Milk (FCM)	FCM per therm
			Grain	Hay		
Lb.		Lb.	Lb.	Lb.	Lb.	Lb.
0.0	16.6	-.45	0	35.2	33.9	2.04
0.4	20.2	+.09	7.8	30.2	39.9	1.98
0.8	23.6	+.79	14.7	26.3	44.5	1.89

1# Grain decreased (hay consumption) 0.61 pound.

Beltsville Experiment

In this study, Holstein cows were fed concentrate, alfalfa hay, and corn silage so that these feeds were available for ad libitum consumption throughout the day. The intake of 3 individual cows from 91 to 120 days during the lactation period is compared to the intake average of all cows in table 5.

Table 5. Results of feeding Holstein cows concentrate, alfalfa hay, and corn silage ad libitum--Beltsville, Md.

Cow	Period	Concentrate	Concentrate therms	Hay	Corn silage	Gain 300 days	FCM 300 days
	Days	Lb/day	%	Lb/day	Lb/day	Lb/day	Lb.
All cows	91-120	33.7	74.0	8.5	34.4	+249	13,211
3880	91-120	51.7	91.1	3.6	14.5	+176	17,873
3683	91-120	18.4	50.0	12.0	56.1	+317	12,241
3678	91-120	28.0	64.7	6.6	47.5	+310	7,363

This experiment involved 19 cows. Of these, three cows failed to complete a 10-month lactation and produced less milk than in their first lactation, yet they consumed nearly 5 percent more energy. Two other cows that completed a 10-month lactation produced less milk than in their first lactation but consumed 32 percent more total energy. Four other cows produced less than

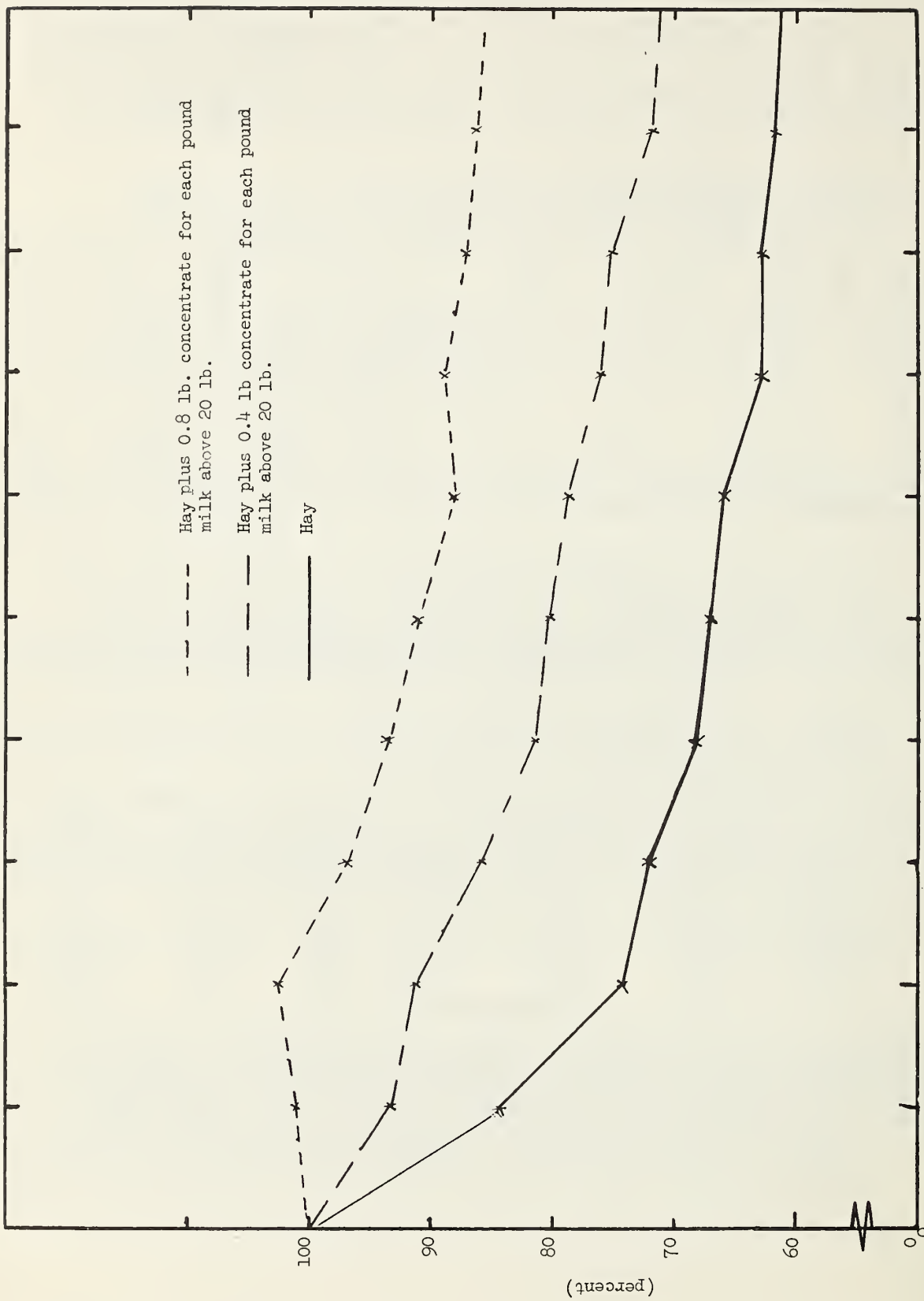

Figure 1.--Relative milk production of cows at three levels of energy intake--Montana experiment.

their expected second lactation yield. The remaining ten cows produced from 104 percent to 133 percent of their expected lactation yield, based on age correction factors. The average feeding level was 130 percent (extremes 106 to 154 percent) of Morrison's requirements.

Each cow had equal opportunity for feed. The contrast in concentrate intake between cow 3880 and cow 3683 illustrates the difference between cows. Whether cow 3683 would have consumed more concentrate if forage had been limited is not known. In spite of the fact that cow 3678 had the opportunity to and did consume almost as much concentrate as the average for all cows, she did not respond in terms of milk production. This cow milked for only 240 days and produced only 7,363 pounds of milk compared to 13,211 pounds for the average of all cows.

None of the cows in this experiment went off feed or had digestive problems. In contrast Jersey cows experimented with at the Lewisburg, Tenn., station were thrown off feed when they received more than 20 pounds of concentrate, although they received liberal amounts of concentrate during the dry period and the concentrate was increased gradually.

OTHER CONSIDERATIONS

Law of Diminishing Returns

As the total amount of concentrate fed to a lactating cow is increased, milk production increases, but the increase in pounds of milk for each successive pound of grain fed occurs at a decreasing rate (table 6). This phenomenon, known as the law of diminishing returns, occurs because the additional grain slightly lowers the digestibility of the ration and also stimulates the deposition of body fat.

At level 2, for instance, 1 additional pound of grain resulted in the production of 16.7 pounds of milk, while at level 13 the additional pound resulted in only 2 pounds of milk. The effects of this law must be taken into consideration when giving consideration to feeding liberal amounts of concentrates.

The validity of the law of diminishing returns has been questioned where applied to liberal concentrate feeding in high-producing dairy cattle. Because of the very great economic significance of the application of the law to the production of milk, further data should be obtained to substantiate or reject the law. On the surface it would seem logical that if increasing amounts of concentrate causes an increase in fat deposition and a depression in digestibility, the law would have to be applicable. In the Michigan, Washington, and Montana experiments previously mentioned, there was evidence of increased weight gain with increased concentrate intake. Whether "extra high" producing cows have been fed or could be fed sufficient energy to bring the law into operation in the flat top portion of the curve of the law of diminishing returns is another consideration.

Table 6. The effect of feeding levels on milk production

Level of feeding from lowest to highest	Milk produced per pound of grain fed during lactation	Grain fed annually	Hay fed annually	Estimated quantities of milk these feeds would produce
	Lb.	Lb.	Lb.	Lb.
1	---	0	11,338	6,488
2	16.7	420	11,048	7,020
3	8.9	840	10,751	7,517
4	6.3	1,260	10,447	7,947
5	5.0	1,680	10,136	8,317
6	4.1	2,100	9,817	8,639
7	3.5	2,520	9,492	8,915
8	3.1	2,940	9,159	9,156
9	2.8	3,360	8,818	9,366
10	2.5	3,780	8,471	9,550
11	2.3	4,200	8,116	9,708
12	2.1	4,620	7,754	9,847
13	2.0	5,040	7,385	9,971

Area of "Economic Indifference"

It has been aptly pointed out that there is an area of economic indifference with liberal concentrate feeding. In other words, the level of concentrate feeding can vary considerably about the point of greatest economic return without greatly affecting the total monetary return. This point is brought into focus in table 7. In this table the value of milk above feed cost was calculated from data obtained in U. S. Department of Agriculture Technical Bulletin 815 by applying certain costs to feed fed and milk produced. For instance, in the second group of calculations $114.30 appears in the box below a feeding rate of 1 pound of grain to 4.1 pounds of milk. However, the figures for 1:5 or 1:3.5 do not differ greatly, being $113.44 and $113.42.

From a practical standpoint, it is probably wise to advise the dairyman to feed on the lower side of the point of greatest economic return in order to avoid the cost of extra handling of concentrates and the production of more "surplus" milk.

Effect of Prepartum Feeding on Subsequent Lactation

An excellent experiment was conducted at the University of Tennessee with 75 pairs of cows on the effect of prepartum concentrate feeding on subsequent lactation. Although 2 different experiments were involved, essentially one animal of each pair was fed 8 pounds of concentrates per day, beginning 42 days before expected parturition, while the pair mate received no concentrates. After parturition, the cows in each pair were fed alike. The concentrate feeding schedule was prepared in advance on the basis of liberal allowance for the expected production of each pair (table 8).

Table 7. Value of milk above feed cost at varying grain to milk ratios[1/]

Item	Ratio of grain to milk								
	00	1:8.9	1:6.3	1:5.0	1:4.1	1:3.5	1:3.1	1:2.5	1:2.0
Milk $4.00/100, hay $30.00/ton, grain $60.00/ton									
Value of milk	257.52	300.68	317.88	332.68	354.56	356.60	366.24	382.00	398.84
Cost of hay	170.07	161.27	156.71	152.04	147.26	142.38	137.39	127.07	110.78
Cost of grain	----	25.20	37.80	50.40	63.00	75.60	88.20	113.40	151.20
Total feed cost	170.07	186.47	194.51	202.44	210.26	217.98	225.59	240.47	261.98
Value of milk above feed cost	87.45	114.21	123.37	130.24	135.30	138.62	140.65	141.53	136.86
Profit on grain	00	26.76	35.92	42.79	47.85	51.17	53.20	54.08	49.41
Milk $4.00/100, hay $30.00/ton, grain $80.00/ton									
Value of milk	257.52	300.68	317.88	332.68	354.56	356.60	366.24	382.00	398.84
Cost of hay	170.07	161.27	156.71	152.04	147.26	142.38	137.39	127.07	110.78
Cost of grain	----	33.60	50.40	67.20	84.00	100.80	117.60	151.20	201.60
Total feed cost		194.87	207.11	219.24	231.26	243.18	254.99	278.27	312.38
Value of milk above feed cost	87.45	105.81	110.77	113.44	114.30	113.42	111.25	103.73	86.46
Profit on grain	00	18.36	23.32	25.99	26.85	25.97	23.80	16.28	-0.99
Milk $4.00/100, hay $20.00/ton, grain $60.00/ton									
Value of milk	257.52	300.68	317.88	332.68	354.56	356.60	366.24	382.00	398.84
Cost of hay	113.38	107.51	104.47	101.36	98.17	94.92	91.59	84.71	73.85
Cost of grain	----	25.20	37.80	50.40	63.00	75.60	88.20	113.40	151.20
Total feed cost	113.38	132.71	142.27	151.76	161.17	170.52	179.79	198.11	225.05
Value of milk above feed cost	144.14	168.97	175.61	180.92	184.39	186.08	186.45	183.89	173.79
Profit on grain	00	24.83	31.47	36.78	40.25	41.94	42.00	39.75	29.65
Milk $4.00/100, hay $20.00/ton, grain $80.00/ton									
Value of milk	257.52	300.68	317.88	332.68	354.56	356.60	366.24	382.00	398.84
Cost of hay	113.38	107.51	104.47	101.36	98.17	94.92	91.59	84.71	73.85
Cost of grain	----	33.60	50.40	67.20	84.00	100.80	117.60	151.20	201.60
Total feed cost	113.38	141.11	154.87	168.56	182.17	195.72	209.19	235.91	275.45
Value of milk above feed cost	144.14	159.57	163.01	164.12	163.39	160.88	157.05	147.09	123.39
Profit on grain	00	15.43	18.87	19.98	19.25	16.74	12.91	2.95	-20.75

[1/] Calculated from data in U. S. Department of Agriculture Technical Bulletin No. 815, table 27.

Table 8. Tennessee prepartum feeding experiment

Item	Dry period feeding		Mean difference
	8 lb concentrate/day and ad lib roughage	Only ad lib roughage	
Number of cows.....	75	75	----
Concentrate fed in dry period (lb).....	304.	0	304.[a]/[1]/
Body weight changes:			
-6 weeks to -1 week (dry) (lb).....	57.5	27.	30.5[a]/
1 week to 6 weeks (lactation) (lb).....	-33.4	-13.1	20.3[a]/
Experimental lactation:			
30 weeks FCM (lb).....	7,970	7,527	443[b]/[1]/
Concentrate fed (lb).....	2,773	2,812	-39

[1]/ Adapted from the work of Swanson, E. W., and Hinton, S. A. Effects of adding concentrates to ad libitum roughage feeding in the dry period. J. Dairy Sci. 45:48-54, Illus. 1962.

a/ Highly significant statistically, $P = < 0.01$; b/ Statistically significant, $P = < 0.05$.

The cows fed concentrates prepartum reached a higher peak production than those not fed concentrate despite equalized feeding after parturition. By the end of lactation, the two groups were producing similar quantities of milk. For the lactation total, the cows fed concentrates prepartum produced 443 pounds more milk for the additional 304 pounds of concentrates fed prior to parturition.

Other investigators have not always observed this effect probably due to the fact that the experimental cows were already in an excellent state of body condition at parturition. Regardless of experimental variation, the purpose should be to stimulate maximum production of milk in early lactation.

There is some indication that liberal prepartum feeding will result in a decreased incidence of ketosis following parturition. Detailed data on this point are lacking.

Minimal Quantities of Forage

The liberal feeding of concentrates to cows reduces the amount of forage consumed. The extent of this reduction depends upon level of concentrate feeding and quality of forage as well as level of milk production, stage of lactation, and probably other factors. In the Montana experiment 1 pound of grain reduced hay consumption by 0.61 pound. Many variable figures can be cited in the literature.

Usually the liberal feeding of concentrates does not reduce forage intake to a point where it would be of practical physiological concern. However, two factors should be kept in mind in this regard.

First, if forage intake is greatly reduced, fat percent in the milk may be reduced. For instance, the milk-fat test of cow 3880 was lowered in the Beltsville ad lib feeding experiment. The lowering of the fat test is thought to be mediated through the changing proportions of acetic and propionic acids in the rumen. The lowering of fat test with liberal grain feeding can occur on a practical basis, but probably does not occur very often.

Secondly, when forage intake is lowered, the possibility of a lower carotene intake becomes greater. This could effect reproduction, and some evidence exists that it could also effect milk production. If the quality of forage is poor so that the intake is low, and the carotene content of the forage is low, vitamin A deficiency becomes a distinct possibility. This difficulty could be overcome by supplementing the concentrate ration with vitamin A. However, today with the quality of forage fed to dairy cattle greatly improved because of early cutting and preservation as silage compared to that of previous years, vitamin A supplementation is not warranted. However, it should be realized that there is a possibility of potential difficulty under certain situations.

Lowering of fat test or vitamin A deficiency is unlikely, provided forage of good quality is fed at a rate of 1 pound of hay or more equivalent per 100 pounds of body weight.

The New Challenge-Feeding Concept

Several methods of liberal concentrate feeding have been proposed. A good one taken from "Southern States Maximum Profit Dairy Program", published by Southern States Cooperative Inc., is given as an example.

1. Breed for production, feed for profit.

2. Provide an 8-week dry period. Feed concentrate to improve condition of cow.

3. Follow the new challenge-feeding concept.

    a. Pre freshen condition all cows: Starting 2 weeks before expected calving date, feed 1 to 1-1/2 pounds of concentrate (grain) daily per hundred pounds of body weight. Increase concentrate feeding to this level gradually. Continue feeding at this rate to freshening.

b. Early lactation full feed: Feed cows to appetite for 30 days after freshening or until peak production is reached.

c. Calculate your feeding rate: Calculate most profitable concentrate feeding rate at 30 days.

d. Be alert for changes: Recalculate as milk production declines and as forage quality changes, or both.

e. Prebreeding condition high-producing cows: Have cows in good condition at breeding time. If necessary, feed additional concentrate 2 weeks before expected heat period.

4. Make and feed good quality forage the year round.

5. Produce and feed good silage the year round.

6. Grow replacements, feed them well, and breed early.

7. Cull low producers.

Calculation of Economic Feeding Rate

The dairyman must have some means of deciding what level of concentrate feeding he should use in relation to the price of concentrates and the price of milk. Through the use of the "Cowculator" by courtesy of Dr. C. D. Caskey, Southern States Cooperative Inc., Baltimore, Md., two graphs were developed for the purpose of serving as a guide to the most profitable level of feeding concentrates. In making the calculations, it was assumed that cows will consume 2.0 pounds of hay equivalent per 100 pounds of body weight. The hay was also assumed to be forage of good average quality. It was also assumed that the cow with milk testing 3.5 percent fat weighed 1200 pounds; the one testing 4.5 percent, 1100 pounds; and the one testing 5.5 percent, 1000 pounds.

The use of figures 2 and 3 can best be illustrated by an example. Let us assume milk is worth $4.75 per 100 pounds; grain, worth $3.30 per 100 pounds, and that you want to know how much grain to feed a cow when she is producing 45 pounds milk daily, testing 4.5 percent fat.

In figure 2 the intersection of the dashed lines indicate that you can afford to feed at level C with milk worth $4.75 and grain worth $3.30. Turning to the columns of figures and letters in figure 3, you can see that you should use line 5 for a cow with milk testing 4.5 percent fat and fed at level C as indicated by the arrow. As indicated by the dashed lines in figure 3, a cow producing 45 pounds milk would need about 20.5 pounds of grain daily. The

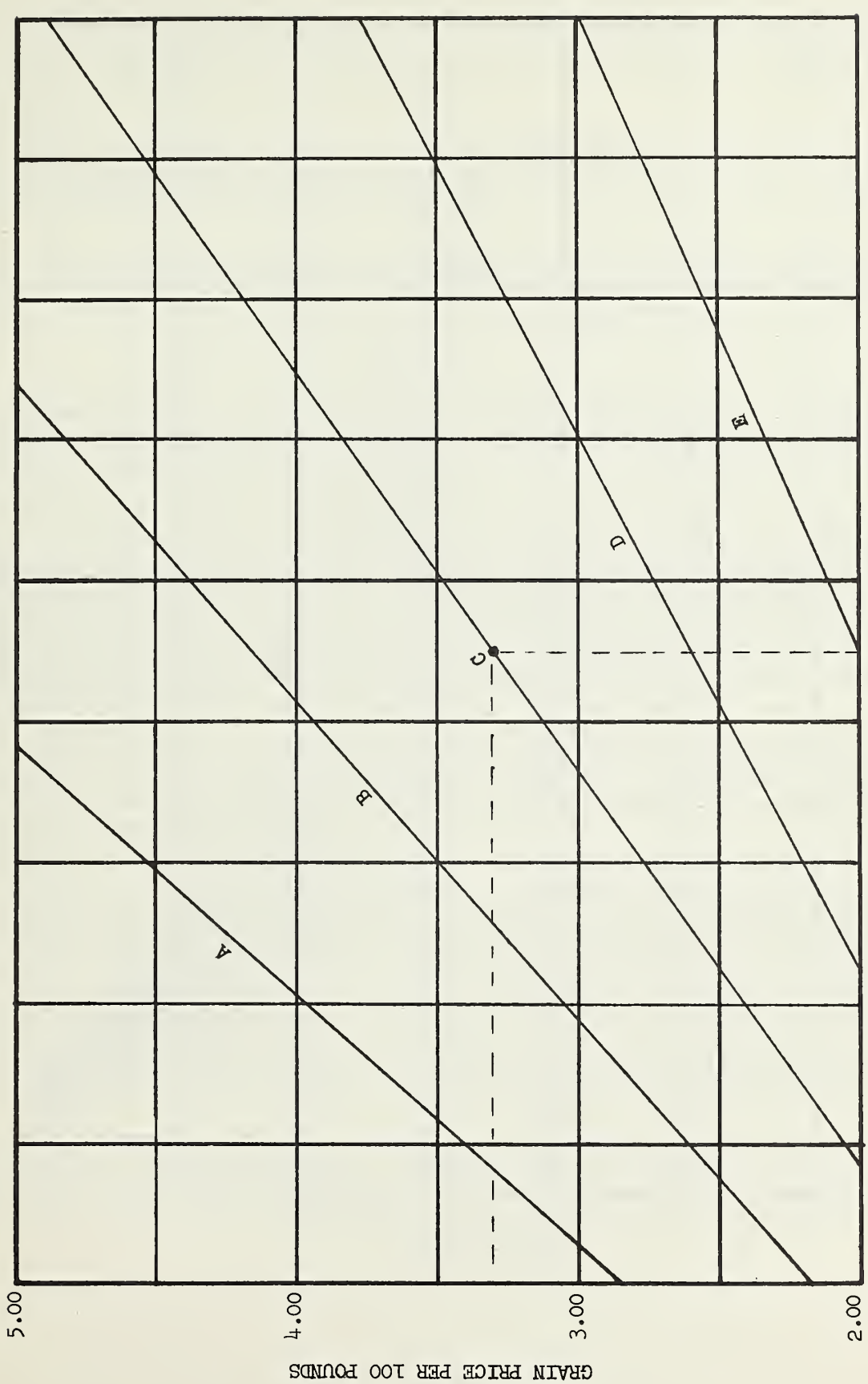

Figure 2.--Most profitable level of feeding in relation to price of milk and grain.

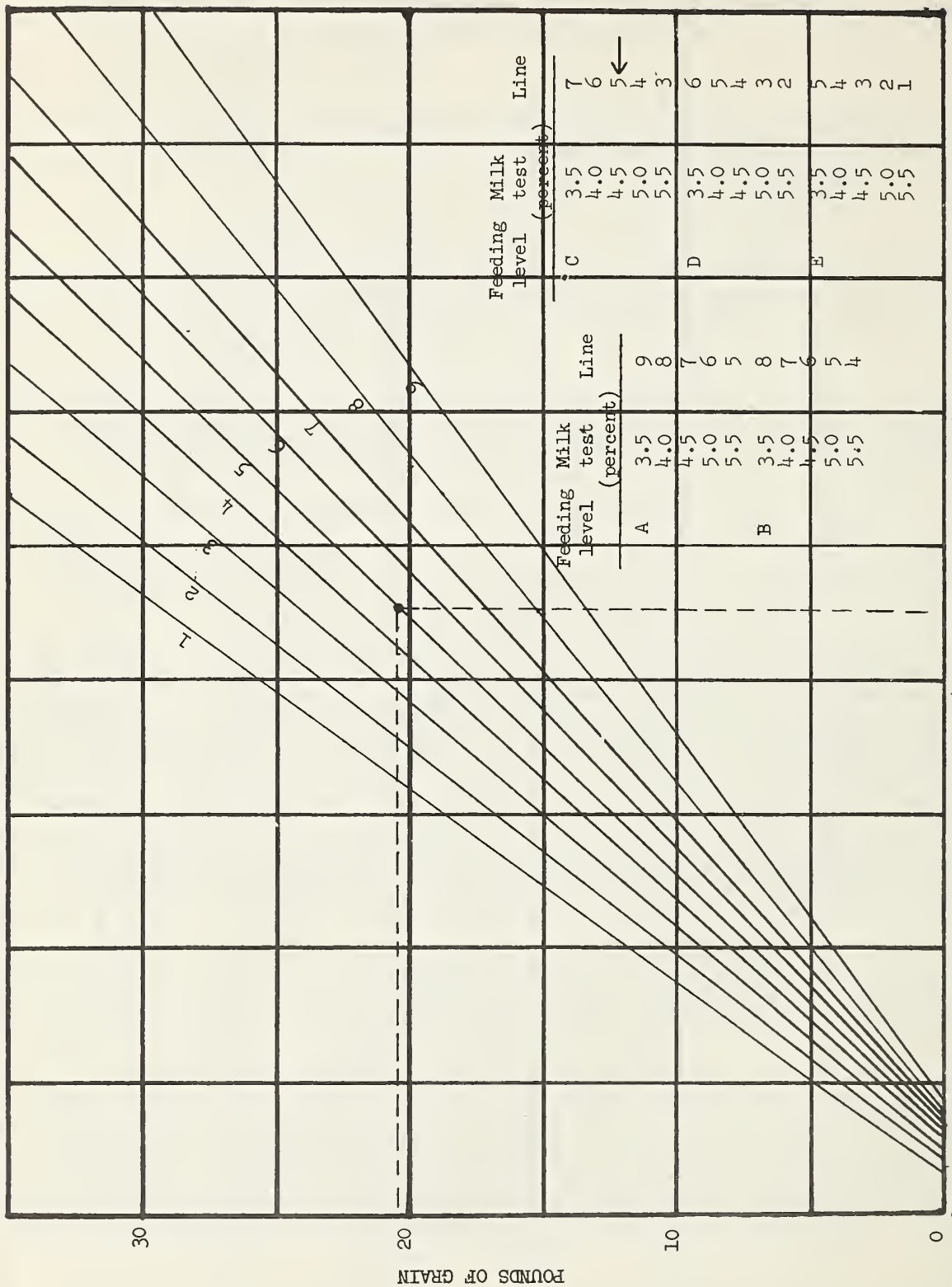

Figure 3.--Daily grain required based on the level of milk produced, percentage of fat, and level of feeding.

pounds of grain to feed for other levels of feeding, milk fat test, and pounds of milk can be similarly estimated. After a proper line has been located to cover a particular feeding level and fat test for the herd, the line can be marked with a colored pencil so that it can be readily distinguished from the other lines.

Feeding level A, in figure 2, represents normal requirements. Each succeeding level represents a 10 percent increase with level E equal to about 140 percent of requirements.

The lines in figure 3 represent concentrate to feed for average quality forage. If the quality of forage is poor, add 4.0 pounds and if it is excellent, subtract 4.0 pounds from the answer obtained on the graph.

DISCUSSION

For maximum response to liberal concentrate feeding, in terms of the total production for the lactation period, present data show that it is desirable to obtain as high a peak of milk production as possible in the early stage of lactation--3 to 6 weeks from parturition.

However, it should also be pointed out that cows will probably respond during any period of the lactation. For instance, in the Montana experiment, all cows during the preliminary period were fed at about 100 percent of requirements (0.4 pound grain for each pound of milk above 20 pounds). Three to four months after lactation started, concentrates were increased to 0.8 pound grain for each pound of milk above 20 pounds, yet the production of some cows increased and persisted.

It is interesting to note at this point that the response to feeding 0.8 pound grain for each pound of milk above 20 pounds in the Montana experiment is similar to that previously observed in other experiments when thyroprotein was added to the ration.

The degree of response is dependent upon the original level of feeding. If the level was low, the response will be great, but if the original level was high, little or no response may be observed in some cows. The same reasoning also holds where total lactations are compared. For instance, in the ad lib Beltsville experiment, in which the mean intake was 130 percent of Morrison's requirements, the lactations were compared to previous lactations in which the feeding level was approximately 115 percent of Morrison's requirements. Had the previous lactation been made at 100 percent of Morrison's requirement rather than 115 percent, possibly a greater response would have been recorded.

From the information available and under advantageous price relationships, it seems logical to recommend that if the base level of nutrition is low (100 percent or below), mass feeding of the entire herd with liberal amounts of concentrate up to 110 to 115 percent of requirements can be practiced, because

it is likely that a large percentage of the cows will respond with increased milk production. On the other hand, if the base level is already at 110 to 115 percent of requirements, as it was in the Beltsville experiment, individual feeding should be practiced because fewer cows will respond to the liberal feeding.

Obviously, there are differences between the response of cows to liberal concentrate feeding, as shown in the Beltsville experiments. It is possible that there are optimum concentrate and forage ratios for maximum milk production. As suggested in the Beltsville experiment by the large differences in concentrate consumption, it is possible that cows may differ in terms of an optimum concentrate to forage ratio, or that they may differ in the optimum proportions of organic acids necessary for efficient milk production, or that they differ in the amounts of organic acids they produce in the rumen.

Evidence also exists in the literature that there may be an optimum ratio of concentrate to forage for weight gain. This ratio could be related to the optimum proportions of organic acids produced in the rumen for optimum utilization of metabolizable energy as suggested in the literature. While not applicable to the Beltsville experiment, it is of interest to point out that concentrates may differ, especially if they have been heated or steamed.

Because of the area of "economic indifference" resulting from the operation of the law of diminishing returns, it seems reasonable to recommend feeding on the lower rather than the upper side of the point of greatest economic return in order to prevent further increasing our already excess supply of milk. Thus, the return in dollars would not be much less if the next lower level of feeding were used than the one indicated in figure 2 by the price of milk and the price of grain.

Whether extra grain should be fed during the dry period depends upon the quality of forage available and the condition of the cow. The cow should approach freshening in good condition, and if she is in poor condition, the feeding of extra grain is justified. Regardless of condition, grain feeding should be started 2 to 3 weeks before calving at the rate of 1 to 1-1/2 pounds per hundred pounds of body weight. This will accustom the rumen of the cow to extra amounts of grain so that she will be able to consume considerable grain after calving without digestive upsets.

Liberal concentrate feeding was developed in the grain producing areas of the Midwest where concentrates are relatively low in cost compared to forages. It is necessary to keep in mind that such a program may not always be applicable to all areas of the United States. The dairyman should produce and feed a greater proportion of those crops which yield the most digestible energy per acre or purchase those feeds in which he can obtain the most digestible energy per dollar.

SUMMARY

Dairymen should approach the liberal concentrate feeding program with moderation. They should satisfy themselves that economics are in their favor.

Experiments have shown that cows vary considerably in their response to heavy grain feeding and in the amount of concentrate they will consume. All cows do not respond. The most profit is obtained from cows that have an inherited capacity for a high level of milk production.

It is not clear at this time what the long-term effect of heavy concentrate feeding will be on herd life or lifetime production. It seems likely that if forage quality is excellent and is not limited, intake will be sufficient to maintain an adequate supply of minerals and vitamins. If forage quality is poor, there may be some question if the supply of minerals and vitamins is adequate. A good grass silage program will help to maintain the supply of good quality forage.

Prepartum feeding for 2 to 3 weeks and being certain that the cow is in excellent condition for calving should be a part of the liberal concentrate feeding program.

The principal key to success in the liberal feeding of concentrates is to obtain a high peak of milk production in the first 3 to 6 weeks of lactation as a base for high milk production during the remaining part of the lactation.

The area of "economic indifference" in terms of dollar returns makes it seem reasonable to recommend feeding on the lower rather than the upper side of the point of greatest economic return in order to prevent adding more milk to our now surplus supply.